Study the performance of multi crystalline silicon wafers in terms of the light trapping ability by the surface modification and its impact on overall efficiency of solar cells

A synopsis submitted

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SWAMI RAMANAND TEERTH MARATHWADA UNIVERSITY, NANDED

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SYNOPSIS

Abstract of proposed work plan/ problem

1. Introduction

Since from ancient times, Sun has been worshiped as a God (life giver) not only in India but also over the entire planet.Sun gives a huge amount of energy in the form of heat and radiation known as solar energy. It is available almost all the places on earth with effectively at free, so it is one of the limitless source of energy for the human being [1].The incident sunlight can be directly converted into electricity by use of photovoltaic solar cells. [2-3]. The conversion efficiency and the low manufacturing cost of solar cell is measure issue on which researchers over the globe working in order to solve energy crises of the world. In the traditional silicon solar cell, when the sunlight strikes on the surface of solar cell, some of the photons get absorbed and solar cell material convert light energy of photons into the electrical power but at the same time few amount of energy get converted into heat and few will be lost in the form of reflection, scattering, etc [4]. In this way, Photovoltaic (PV) where the conversion of sunlight to electricity occurs is a promising technology that could provide feasibility for the generation of electrical power on a very large scale and possibly solving the energy problem for the next generation [5].

Geographical condition of India naturally gifted with vast solar energy potential. About 5,000 trillion kWh per year energy falls over India's land with approximately 4-7 kWh/m^2/ day [6].Therefore, effective harnessing of solar photovoltaic power provides huge scalability for electricity generation in India. From an energy security perspective also, solar energy is the most secure of all sources, since it is abundantly available. If a small fraction of the total incident solar energy captured effectively, it can meet the entire country's power requirements. At present, mono and poly crystalline silicon (c-Si) wafer-based solar cells contribute to-over 90% of commercial photovoltaic (PV) devices [6]. While thin film based solar cells comprises of different absorber layers also becoming popular with the enhanced efficiency.In case of thin film multi layer based solar cell, different layers in one cell reduce the energy loss in solar cell i.e. with the falling of incident light at the solar cell, and photons will be trapped and absorbed by layers which helps preventing the energy wastage of cells[5]. In spite of the advantages of the thin film, traditional solar cells are still leading the market by more than 80% coverage due to overall cost required to develop thin film technology for solar cell. In case of crystalline

based silicon cell, reducing losses of incident photons and managing heat generation during conversion are the measure issues. Recently, many researchers have provided feasible data in which efficiency of solar cell has been improved significantly by processing the solar cell surfaces with laser light which modifies its surface micro structured arrangement results into improvement in the light trapping ability which consequently improve conversion efficiency of solar cell successfully.

Review of literature and development in the subject

(International and National status of proposed work)

In the photovoltaic industry, the panels builds on the base of crystalline silicon wafers exceed over of the global production, among that one third of which is produced from mono crystalline silicon and remaining from poly crystalline silicon [6]. Among all kinds of silicon photovoltaic cells,Mono crystalline based photovoltaic cells are characterized by the highest efficiency but at the same time consume the highest production costs[7]. The conversion efficiency of photovoltaic cell prototypes in laboratory tests is achieved up to 24%, while the efficiency for the mass produced solar cells in industry shown efficiency up to 17% [7, 8].Solar cells made of poly crystalline silicon have lower efficiency however required lower manufacturing cost than those made of mono crystalline silicon because of the absence of the costs associated with the energy-intensive single crystal manufacturing process [8,9].Research on photovoltaic systems is still relevant as the tendency of the world is towards the reduction of carbon dioxide emissions. New methods are developing for placing solar cells not only in typical locations, such as free-standing photovoltaic farms or roofs, but also in windows [10], even on small surfaces, e.g., on textiles [11], as well the methods of producing cells with shapes different than the typical one [12], or to power whole zero/low energy buildings using various optimization methods [13].

The majority of the solar cells are made using crystalline Silicon wafers. Industry uses two types of the crystalline Silicon i.e. the multi-crystalline Silicon (mc-Si) and mono crystalline silicons respectively. mc-Si offers lower production cost which is highly desirable for the large-scale applications. But at the same time mc-Si multi-crystalline Silicon solar cells usually suffer from lower efficiencies than mono-crystalline Silicon solar cells counterparts because of lower carrier lifetime and lower surface and interface qualities [14]. In order to improve the surface structure, and so that have higher light absorption rate, the surface of multi crystalline Silicon solar cells get textured. Texturing of mono crystalline silicon wafers can be done by various

methods like using an isotropic alkaline solutions which create micro-textured pyramids at the surface. The industrial chemical solutions like KOH and IPA can also be used on mono crystalline Silicon as chemical etching on particular plane of surface in order to formation of pyramids [15]. For the mc-Si wafers, texturing process using the above an isotropic is not practical because of the presence of random crystallographic grains on their surface [16,17].

Other researchers also reported for enhancing the mc-Si solar cells' efficiency by improving the light absorption from the front surface via texturing it. Few other techniques also reported including Metal-Assisted Etching (MAE) in which metal-catalyzed etching followed by post alkaline etching is used to fabricate nanosecond pseudo-pyramid texture [18] followed by a post Nona-Structure Rebuilding (NSR) solution treatment [8] which can have efficiency more than 18% [19]; Reactive Ion Etching (RIE) in which random texture in Nona-structured Silicon surface is also investigated [20] with few advancements like a mask-less RIE in O_2 and SF_6 plasma [21]. Among all the surface processing methods, laser texturing is a promising alternative. Laser structuring silicon wafer is introduced backs to 1989 by J. C. Zolper et al. and M. A. Green [22]. A notable use of laser texturing as a black Silicon presented by Tsing-Hua et al. and Eric Mazur at 1998 [23] in which authors used femtosecond pulsed laser for surface micro structuring [24]. Some Other researchers used the same technique and focused on texturing of silicon wafers [24] in which laser texturing has been used to obtain cone array micro structure [24]. In the laser texturing method, a laser beam is scanned across the surface to create grooves with dots or line shapes like structures. The laser processing parameters are optimized as per the desired surface pattern and morphology [25]. The shape, depth, and spacing of these laser-ablated micro structures showed a significant role in determining the reflectivity and trapping of light from the modified surface [25]. Many investigations are reported by changing different laser parameters like using nanosecond UV laser with the spot size of 100 mm without post-texture cleaning obtained 19.9%efficiency for mono-crystalline samples and 17.9% efficiency for mc-Si samples respectively [26]. Implementation of Picosecond laser with the optical comparison between different laser wavelengths is also reported [27]; the use of IR laser for the texturing purpose is also reported [27].

2. Objectives of the research

The main objective of my thesis is to improve the performance of multi crystalline silicon wafers in terms of the light trapping ability by surface modifications using various methods in order to improve overall efficiency of solar cells

The intermediate objectives in order to justify the above purpose are:

- Study the different micro structural designs and its significance on reflection coefficient of surface.
- Optimize micro structural parameters using theoretical analysis
- Create micro structures on mi-Si wafer surfaces using different method including laser based surface modification, chemical based surface modification or reactive ion based surface modification, etc.
- Experimental study of mi-Si wafers in terms of modified optical properties using natural sun light and non coherent white light source.
- Comparison and Measurement of electrical conversion efficiency using standard method

3. Methodology

The refractive index of silicon is very high therefore the reflection losses at the surface of solar cells for incident electromagnetic spectrum of sun light are comparatively high.The different experimental methods will be designed for surface texturization in order to reduce the reflection and increase the absorption coefficient respectively. The provisional will be made to optimize surface texturing parameters in the range of 01 to 100 micron for multi crystalline silicon material for several type of texturization technique including laser based surface treatment, acid texturization , reactive ion etching, and mechanical texturization. Experiments will be carried out on P-type boron doped and N-type phosphorous doped multi crystalline silicon wafers respectively. The topography of textured surface will be investigated by Scanning Electron Microscopy (SEM) and an Atomic Force Microscopy (AFM). Furthermore, the textured surfaces of multi crystalline silicon wafers reflectance and absorption for natural sun light and white light sources will be measured using a standard spectrometer in with range covers from UV-VIS-IR respectively. Overall conversion efficiency of surface modified poly crystalline silicon wafers will be measured by standard I-V measurement technique respectively.

4. Importance of study / society applications

Now a day's, Solar energy is becoming unlimited and environment-friendly and the most affordable renewable energy source in India. Different Types of solar panels are going to be used in home and industrial applications. As fossil fuels (crude oil based) and electricity charges are getting expensive due to overall limited resources so we have to shift towards eco-friendly sources like solar energy. Therefore, the demand for solar panels is increasing in recent years across globe and India. Solar panels are mainly based on mono crystalline silicon material or the multi crystalline silicon material. Among of both, mono crystalline silicon material is popular one due to its high conversion efficiency. But in the prospect of economic feasibility and availability of development technology, use of mono crystalline based solar panel is expensive for the developing countries including India. Because of this reason, utilization of solar energy is not speeding up in spite of heavy demands. In case of Poly crystalline which also known as multi-crystalline solar panels are considered to be less efficient than mono crystalline panels, which is estimated to be around 13-16%..But it is comparatively more cost-friendly and development technology is easily available in India. My research is an experimental and theoretical approach towards increase in overall efficiency of multi crystalline silicon wafers. The literature review and background study confirms that there are feasible methods available which can provide significant improvement in the efficiency. Among of them, surface modification of solar panel is most promising. As the research published on solar cell efficiency concludes that losses of incident sun light from solar panel due to reflection, scattering and low absorption also heat dissipation rate are the major issues responsible for reduction in the efficiency. Surface modification provides an opportunity to overcome this drawback. My research plan is to figure out suitable methodology to develop optimized surface textured multi crystalline solar panel with improved overall efficiency. This research helps to overcome current disadvantages of multi crystalline solar cells and promote the development of solar panels in India in the more eco-friendly way.

5. Significance of the study

My research work is based on reference data as mentioned in the literature review which is going to be further extended by me in order to provide economically cheap and with the improved performance for multi crystalline solar wafers. The study in particular will be useful in the form of three measure thrusts : (i) combining and optimizing laser based surface texturing process provide the feasibility of single step modification process (ii) The present research which lead to methodology which provide economically cheaper solution with improved performance for multi crystalline silicon wafers (iii) The proposed research will lead towards the methodology which confirms repeatability and atomization with this mass production in the relevant field also become possible. The result obtained by carrying out this research work is beneficial to encourage the usage of solar cell in the developing country like India with promising energy alternative for industrial, household and farming applications.

6. Proposed work plan/ formulation and structure of study:

The proposed topic involved both the theoretical and experimental study of photovoltaic effect in solar cell based on multi crystalline silicon material. In the theory part, research work is planned including understand and review the light trapping model to enhance the performance of the solar cell available in the literature, theoretical analysis to adopt the possible methodology for measure

I-V properties of solar cell devices etc. In the experimental part initially the microscopic study of unprocessed surface of multi crystalline silicon wafers is being planned with the available microscope. This study will confirm the surface quality and grain distribution of surface of selected silicon wafer. Consequently, the optical properties including reflectivity; refractivity and absorption will be measured for natural sun light and commercially available white light sources. After the preliminary observation of surface quality, different designs of micro-structure will be finalized for surface texturing based on theoretical study and analysis in order to optimize the optical properties of multi crystalline silicon wafers. The feasibility of micro-structure development of surface of mi-Si surface will be confirmed among the available fabrication methods including laser surface processing, chemical etching based processing or plasma based etching processing, etc. The characterization will be carried out for processed sample by means of XRD, AFM, SEM, EDAS, TGA-DTA and FTIR as per the requirements.

The provisional will be made to test the optical performance of mi-Si wafer for solar electromagnetic spectrum and optimization of micro structure parameters will be done accordingly. In order to measure the conversion efficiency of modified silicon wafers, devoted experimental set up of IV measurement using two probe and four probe experiment will be planned. Finally, the optimization to illustrate the improvement in light trapping ability and its impact on conversion efficiency will be done in order to demonstrate the developed methodology to improve the performance of multi crystalline silicon wafers as solar cell device.

7. Year wise plan

The PhD research work will be carried out as per the time duration listed below:

FIRST YEAR: Completion of Pre - PhD. Course work, Literature Survey, Theoretical analysis, Synthesis of Samples, Design of experimental setup to gate expertise in handling sophisticated instruments for silicon wafers, optical sources, voltage sources etc and characterization techniques like XRD, FTIR, SEM, EDAS and AFM. Development of the experimental set up to measure the optical properties of silicon samples and its standardization. Participation in conferences/Symposium.

SECOND YEAR: Characterization of samples by XRD, FTIR, SEM, EDAS, AFM, TG/DTA, etc. for physical and chemical investigations microscopic study of sample surface, perform experiment to measure light trapping ability and photovoltaic effect for processed silicon wafers. Paper publications, Participation and presentation in International conferences and reputed journals.

THIRD YEAR: Investigation of behaviour of modified multi crystalline silicon wafers as solar cell. Paper publications. Thesis writing and submission.

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